

Strain controlled triaxial test- geotechnical engineering

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1. INTRODUCTION From civil engineering view, Soil is the medium through which the structural loads are transferred safely and efficiently. Soil should be consistent enough to satisfy the requirements even under inevitable circumstances like earthquake, bomb reactions etc. It is necessary to incorporate the seismic effects into the soil properties. Like concrete or steel, engineering properties of soil cannot be found out using theory of classical dynamics and vibrations. It can be found only field and lab tests.

To quench the above requirement, various techniques are employed nowadays. The most common methods are cyclic simple shear, cyclic triaxial shear and cyclic torsional shear tests. The dynamic triaxial test is the most effective method to arrive the static and dynamic properties of soil like cyclic deformation, damping ratio, liquefaction strength etc. Though it has some limitations, it is widely used for the analysis of soil under seismic forces. The fundamental parameters obtained from this test are cyclic shear stress and cyclic shear strain, through which the soil is defined.

The tests can be done either by stress controlled (cyclic shear stress) or strain controlled (cyclic shear strain). The test setups are highly sophisticated and costly. It needs highly skilled labour. The measuring devices used in the system needs to be calibrated and sealed properly as it is more sensitive to disturbances. The results obtained reflect the site seismic condition to the maximum level provided the strain level is kept minimum. Fig 1. 1 Triaxial Cell Fig 1. 2. A typical Cyclic triaxial apparatus 1.

1 WHY DYNAMIC TRIAXIAL

The Dynamic forces are time dependent and are usually cyclic in nature i. e. they involve several cycles of loading, unloading and reloading. Earthquake is three dimensional in nature. Hence the shear waves and body waves produced by the earthquake tend to deform the soil in all the directions (for the horizontal level ground). Dynamic Triaxial tests actually reflect the soil condition (in all round stresses) in the site. During earthquakes, the seismic waves cause the loose sand to contract and thereby increasing the pore water pressure.

Under undrained loading, development of high pore pressure results in upward flow of water, thereby making the sand in liquefied condition. Pore water pressure is measured effectively in triaxial tests. Among the stress-control and strain-control condition, strain control is adopted widely. This is because; stress-control test has great sensitivity to the sample disturbance. In case of strain-control, pore pressure developed during tests is less affected by specimen fabric and density. The tests can be done on intact specimens and reconstituted specimens.

While comparing the results obtained from intact and reconstituted specimens, there is much deviation in stress-control compared to strain-control. (tests done by vucetic and dobry, in 1988). Stress path control is used in the study of path dependence of soil behaviour. Stress deformation and strength characteristics depend on initial static stress field, initial void ratio, pulsating stress level and the frequency of loading.

There are variety of engineering problems which rely heavily on the behaviour of soils under dynamic conditions.

These includes design and the remediation Of machine foundation, geotechnical earthquake engineering, protection against construction vibration, non-destructive characterization of the subsurface, design of offshore structures, screening of rail and traffic induced vibrations, vibration isolation etc. When it comes to dynamic triaxial test, the wide range of application is the liquefaction behaviour of soil under seismic forces. 2.

HISTORY One of the first pieces of equipment designed to test cyclic triaxial loading was the pendulum loading apparatus by Casagrande and Shannon in 1949.

This utilizes the energy of the a pendulum which when released from a selected height, strikes a spring connected to the piston rod of a hydraulic cylinder, this cylinder is further connected to another cylinder located above the cel. The time of loading was between 0. 05 and 0. 01 sec. Fig. 2. 1.

Pendulum Loading Apparatus Casagrande and Shannon came up with an equipment called Falling Beam Apparatus as shown in Fig. 2. 2 In 1960, Seed and fead used Pneumatic System for cyclic loading. It marks the evolution of the dynamic triaxial shear apparatus. Fig. 2. 2. Falling Beam Apparatus 3.

PRINCIPLE First attempt was made by Seed and Lee (1966) by consolidating a saturated sample under a confining pressure and subjected to constant amplitude cyclic axial stress under undrained conditions. This test was performed till they deformed to a certain amount of peak axial strain. Under this condition creates a stress conditions on a plane of 45° through the sample which is the same as those produced on the horizontal plane in the

ground during earthquakes. This is the basis on which the cyclic triaxial test works. Fig. 3. 1. Simulation of geostatic and cyclic stress in triaxial test.

Shear stress is taken into account as it causes deformation. To incorporate seismic effects, uniform shear stress for a given cycle is adopted for non-uniform stress time data. To achieve that a maximum shear stress is multiplied by a correction factor γ . Then the test is carried out till required deformation or failure to occur. 4. EQUIPMENT 4. 1. Parts of Dynamic triaxial apparatus suggested by ASTM D 3999 – 91(2003)

APPARATUS PURPOSE CONSIDERATION 1. Triaxial Pressure Cell To mount sample and conduct test Tolerance for piston, top platen & low friction piston seal.

Ball bearings and friction seal To minimise friction Friction can be, $\pm 2\%$ of the maximum single amplitude cyclic load Load rod To facilitate loading $d = 1/6$ th of specimen dia Specimen cap & Base To provide a sealed platform Rigid, non corrosive, impermeable, Cap weight $< 0.5\%$ of applied axial failure load (static), Valves To regulate back pressure, cell pressure, pore water pressure Leak-proof, withstand applied pressure Top and bottom platens To facilitate loading and provide a rigid base Proper alignment, load rod sealed with top platen with friction seal. 2.

Cyclic Loading Equipment To induce cyclic loads Uniform sine wave @ 0.1 to 2 Hz, simple ram or a closed loop electro hydraulic system 3. Recording Equipments To record the data obtained Properly calibrated Load Measurement To measure the cyclic loads Electrical, analog or digital Axial deformation Measurement To measure the strain rate LVDT or dial gauges

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Pressure Control To regulate cell pressure Mercury or pneumatic device
 Pore Pressure transducer To measure pore pressure Transducers or electronic pressure meters
 Volume change Measurement To check the volume change in the specimen
 Calibrated and widely used gauges 3.

Miscellaneous a. Rubber membrane b. Filter paper To hold the specimen To facilitate saturation
 Leak-proof with minimum restraint Must not cover more than 50% of the specimen. Fig. 4. 1. Schematic Diagram of a strain-controlled dynamic triaxial test
 4. 2 WORKING PROCEDURE The working mechanism mainly involves three phases
 a) Saturation phase: Initially the sand is sample saturated by applying cell and back pressure simultaneously. (cell pressure > back pressure)
 b) Consolidation phase: during test, void ratio should be kept constant. It is obtained in this phase. Back pressure valve is closed.
) Load Phase: Actual test begins here. Strain rate is fixed using gear system. Cyclic load is applied either using hydraulic or pneumatic type. Loads and corresponding strains are recorded at loading, unloading and reloading. Test is continued until the required strain or failure occurs. 5. RESULTS From the cyclic triaxial test, we can obtain various graphs for detailed analysis,
 • Load Vs Deformation • Deviatoric Stress Vs Time • Axial Strain (%) Vs Time • Excess Pore Pressure Vs Axial Strain (%) • Excess Pore Pressure Vs Time • Deviatoric Stress Vs Axial Strain (%) Fig. 5. 1. Axial load Vs. axial deformation

From the hysteresis loop obtained, the dynamic Young's modulus (E_d) can be calculated, from which shear modulus (G) can be calculated using poisson's ratio (μ). Damping factor (D) can also be calculated from the loop obtained.

Shear Modulus, $G = E_d / 2(1+\mu)$ Damping factor, $D = A_i / 4$ At A_i ? Area of Loop At ? Area of shaded portion 6. Discussions: Two series of undrained cyclic triaxial strain controlled tests were performed by Mladen Vucetic and Richardo Dobry, on two different Imperial Valley, California, silty sands which liquefied during an earthquake in 1981. Both intact and reconstituted specimens were tested.

The cyclic shear strain is the fundamental parameter governing pore pressure buildup. The saturated deposit is composed of two layers: an upper, looser, sandy silt unit located between 2.6 m and 3.5 m depth, containing more fines (37%) (sand A), and the lower, loose to medium-dense sand unit located between 3.5 m and 6.8 m, containing less fines (25%) and (sand B). Selected plots of normalized cyclic shear stress, $\tau_{cy}^* = \tau_{cy} / c_v$, and normalized residual pore pressure, $u^* = u / c_v$, versus number of uniform strain cycles, n_c , up to $n_c = 30$, are shown in Figs. 6.1 and 4 for sands A and B, respectively, τ_{cy} above is the amplitude of cyclic shear stress acting on 45° planes within the specimen, with $\tau_{cy} = \tau_{dc} / 2$, where τ_{dc} is the cyclic deviatoric stress amplitude, and u is the accumulated residual cyclic pore pressure at the end of the pertinent strain cycle, derived from measurements at the point of the cycle at which the cyclic stress $\tau_{dc} = \tau_{cy} = 0$. Fig. 6.1 Comparison of results obtained on intact and reconstituted specimens of sand A The effect of sand fabric, that is, the difference between results obtained on reconstituted and intact specimens, is analyzed next for both sands A and B, with the help of Figs. . 1 and 6. 2. It can be readily noticed in these two figures that the residual pore pressures in cyclic triaxial strain-controlled tests are practically unaffected by the change of sand fabric

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(u^* versus nc curves), while, on the contrary, soil stiffness is significantly affected (γ_{cy}^* versus nc curves). This is especially noticeable in Fig. 6. 2. Fig. 6. 2 Comparison of results obtained on intact and reconstituted specimens of B. Fig. 6. 3 Residual pore pressure in reconstituted specimens of sands A and sand B It must also be noticed that the range of cyclic shear stresses measured at a given cyclic strain in Figs. . 1 and 6. 2, for the two sands and for the two types of specimen fabric, is quite wide, in contrast to the corresponding range of pore pressures in Fig. 6. 3, which is very narrow. This confirms once again that cyclic shear strain is the fundamental parameter governing pore pressure buildup, and that use of strain-controlled testing represents the most appropriate, as well as the most convenient, approach currently available for evaluation of seismic pore pressures and liquefaction of level ground sites. 7. FACTORS AFFECTING CYCLIC STRENGTH

Effect of Confining Stress Critical void ratio is not a constant but decreases as confining pressure increases. The stress ratio decreases with increasing confining pressure. Effect of Loading Wave Form As the load data obtained from history are converted into uniform cycle by ?. The order of increasing strength was rectangular, triangular and sine Effects of Frequency on Cyclic Strength The frequency effects have only a minor (< 10 percent) effect on cyclic strength of the soils. The slower loading frequency have slightly higher strength.

Effects of Relative Density At relative densities < 50%, complete liquefaction occurred almost simultaneously, and relative densities above 70% were required for safety against large strains. Effects of size & Gradation Well-

graded material was somewhat weaker than uniformly graded material. This finding was attributed to a greater densification tendency in well-graded soils, as finer particles move into voids between larger particles, than occurs in uniformly graded soils. This densification tendency causes increased pore pressure.

Effects of sampling on strain history Once a specimen has liquefied and reconsolidated to a denser structure, despite this densification, the specimen is much weaker to cyclic stresses reapplied. Effects of Over consolidation Ratio and K_0 The maximum deviator stress required to cause a critical strain for a specified number of cycle's increases with the K_0 ratio. Also the cyclic strength increases as OCR and fines content increase. 8. VALIDATION The validation of the apparatus is done by successive tests, researcher's experience and available equipments.

Mladen vucetic and richardo dobry conducted two series (Intact and Reconstituted Specimens) of undrained cyclic triaxial tests on Imperial Valley, California, silty sands which liquefied during an earthquake in 1981. The results were compared and the experimental set up was validated. Further the tests were conducted on different types of sand and validated. 9. DEVELOPMENTS Since 1966, there has been a considerable improvements in the triaxial testing apparatus meeting results of higher accuracy and efficiency. Initially stress controlled methods were used, then strain controlled methods were adopted.

To apply loads, initially hydraulic jack was used, then pneumatic system was used and then electro piezometer. Likewise there are so many

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advancements of triaxial tests. Some of the advancements are discussed below. Chan (1981), and Li et al (1988) Fig. 7. 1. , have developed a popular electro-pneumatic apparatus which incorporates many advancements in apparatus design and operation. Fig. 9. 1. Electro-pneumatic Apparatus Automated Cyclic Triaxial system is the next development, which is the most commonly used apparatus. It is well known for its automated input and output

System, data acquisition and quick results. Fig. 9. 2. Automated Triaxial System

9. 1 RECENT ADVANCEMENTS GDS Entry level Dynamic triaxial testing system ? Technical Specifications ? Maximum Operating Frequency: 5Hz ? Minimum Operating Frequency: < 0. 001Hz ? Highly accurate dynamic, electro-mechanical actuator ? Available sample sizes (depending on cell selection): ?? 38 x 76mm (or ? 39. 1 x 78. 2mm) to ? 150 x 300mm. Fig. 9. 3. GDS ELD ? 16-Bit dynamic data logging ? 16 Bit dynamic actuator control channel ? Cell pressure range to 2MPa (dependent of cell choice) ? Small laboratory foot print No hydraulic power pack required ? Standard Triaxial cells can be used (upgraded to dynamic seals and bearings) ? Can be upgraded to perform P and S wave bender element testing. ? Can be upgraded to perform unsaturated triaxial testing with the addition of the following items: a)Unsaturated pedestal with high air entry porous stone. b)1000cc digital air Pressure/volume controller (ADVDPC) for the application of pore air pressure and measurement of air volume change c)Optional HKUST double cell (available in the data sheet ' Unsaturated Triaxial Testing of Soil (UNSAT).

As well as dynamic triaxial tests, the ELDyn system can be utilised to carry out traditional triaxial tests such as UU, CU and CD as well as more advanced tests such as stress paths, K0 and Resilient Modulus tests. HS28. 610 cyclic triaxial test system is also a sophisticated apparatus available in Newdelhi (India). DYNATRIAX is another advanced cyclic triaxial equipment available at many places Los Angeles, Poland and many countries. It can operate at a maximum frequency of 10Hz. 10. CONCLUSION Many innovative systems for cyclic loading of soil have emerged in geotechnical engineering.

Each system has its unique advantages and limitations. Some ways of minimizing these limitations have been pointed out. The advanced equipments are an additional tool for performing cyclic loading, in particular liquefaction testing. Extreme care must be used in preparing remoulded sand specimens, and special attention must be paid to testing techniques in order to obtain reproducible test results. In particular, the method of specimen preparation, the shape of the loading wave form, and the preciseness of density determinations greatly affect cyclic strength.

Hence, development of ASTM standards for cyclic triaxial testing should include consideration of these factors in the results of this investigation. 11.

REFERENCES: ASTM D 3999 Determination of Modulus and Damping Properties of Soils Using the Cyclic Triaxial Apparatus Advanced triaxial testing of soil and rock - Page 484 by Robert T. Donaghe, Ronald C. Chaney, Marshall L. Silver Chan, C. K. , 1981, " An Electropneumatic Cyclic Loading System," Geotechnical Testing Journal, ASTM, Vol. 4, No. 4, pp. 183-187.

Dynamic Geotechnical Testing H Ronald J. Ebelhar, Vincent P. Drnevich, and Bruce L. Kutter. STP 1213 ASTM Publication

Dynamic Geotechnical Testing : a symposium by Marshall L. Silver Khosla, V. K. and Singh, R. D. , " Apparatus for Cyclic Stress Path Testing," Geoteehnicl Testing Journal, GTJODJ, Vol. 6, No. 4, Dec. 1983, pp. t65-172. Fundamental of Soil Dynamics and Earthquake Engineering By Prasad. Soil Liquefaction, a critical state approach by Mike Jefferies & Ken Been Kramer, Steven L. , Geotechnical Earthquake Engineering, Prentice-Hall, Inc. , Upper Saddle River, NJ, 1996 Townsend, F. C, " A Review of Factors Affecting Cyclic Triaxial Teste," Dynamic Geotechnical Testing, ASTM STP 654, American Society for Testing and Materials, 1978, pp. 356-383.